ON THE

ORIGIN

OF

ALLUVIAL AND DILUVIAL FORMATIONS.

BY PROF. SEDGWICK.

FROM THE *ANNALS OF PHILOSOPHY* FOR *APRIL* AND *JULY*, 1825.

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ORIGIN, &c.

(To the Editors of the *Annals of Philosophy.*)

GENTLEMEN, *Trinity College, Cambridge, March* 11, 1825.

THE existence of widely extended masses of incoherent materials separating the vegetable soil from the solid strata of the earth, is a fact which forces itself upon the attention of every practical geologist. These materials have for many years been divided into two classes. The first composed of a series of deposits originating in such causes as are now in daily action. The second composed of various materials irregularly heaped together, often transported from considerable distances, and supposed to have originated in some great irregular inundation. Since the publication of Cuvier's great work on fossil quadrupeds, this distinction has been very generally admitted; especially as it seemed to be completely borne out by the zoological phenomena exhibited by the two separate classes of deposits.

Prof. Buckland was, I believe, the first geologist who adopted the terms *diluvium* and *alluvium*, *diluvial detritus* and *post-diluvial detritus* to designate the two classes of phenomena above alluded to. The propriety of this separation has been since confirmed by a long series of well-conducted observations; and by the interesting discoveries brought to light by the same author within the last four years, some important errors have been corrected, and the whole subject has assumed a form and a consistency which it unquestionably never had before. Since the publication of the "Reliquiæ Diluvianæ," many objections have been urged against the opinions advanced in that work. The greater part of the objectors are undeserving of any animadversion, as they appear entirely ignorant of the very elements of geology, and far too imperfectly acquainted with the facts about which they write to have it in their power to turn them to any

account, or to draw a single just conclusion from them. This censure does not, however, apply equally to them all. A writer in the two last numbers of the Edinburgh Philosophical Journal considers the present classification of the superficial *detritus* of the earth to be founded on an imperfect induction, and to be contradicted, or at least invalidated, by the distribution of the organic remains contained in it. Though I am opposed to many of the conclusions of this author, and think that he has been misled from a want of a more extended knowledge of the phenomena in question, yet I willingly allow that his arguments are adduced with a sincere love of truth, and that his facts and inferences are entitled to a candid examination. It is not, however, my intention formally to enter the field of controversy. Prof. Buckland is far too secure in his position, and incomparably too well armed to need any such assistance.

The words *alluvial* and *diluvial detritus* designate certain classes of phenomena which at the same time have a distinct character, and belong to distinct epochs. The propriety of this assumption can only be made out by direct observation. If it appear that *alluvial* formations commonly rest on *diluvial;* that the converse is never true; and that the two formations never alternate: then the distinction just alluded to is completely made out, and rests on exactly the same evidence as the order of superposition of any known strata. We may further observe that this conclusion is quite independent of any zoological arrangements. When the order of superposition has been once made out, we may then proceed to examine the zoological phenomena of each successive deposit. Before that time, organic remains, however interesting in themselves, convey little information respecting the revolutions to which the earth's surface has been subjected. It has been already observed that the words *diluvial detritus* were applied to certain materials brought into their present situation by great irregular inundations. In what sense all *diluvial* formations may be considered contemporaneous; to what extent, and in what manner, diluvial torrents have acted on the earth's surface, are simply questions of fact to be determined by physical evidence, and by physical evidence alone.

The truth of any physical phenomenon can only be made out by physical evidence, and no appeal ought to be made to any other authority before that evidence has been completely investigated. It is then obvious that every conclusion respecting the classification of formations, of whatever age, can only rest on the evidence afforded by direct observations. For this reason, I have drawn up, for insertion in the *Annals of Philosophy*, an account of some of the *alluvial* and *diluvial* deposits which I have had an opportunity of personally examining. Part of the succeeding statements may be considered unnecessary, and

some of the facts may be thought too unimportant to deserve any notice. If, however, they should throw any light on a disputed subject, or should they in any way strengthen the chain of evidence by which one of the most important inductions of geology has been established, they will not be altogether without their use. I have the honour to be, Gentlemen,

Your most faithful servant,

A. SEDGWICK.

SECT. 1.—*Alluvial Deposits.*

All the principal vallies of England exhibit in their higher portions occasional examples of nearly horizontal deposits of comminuted gravel, silt, loam, and other materials accumulated by successive partial inundations. The nature of these *alluvial* deposits and the cause of them are so obvious, that it is unnecessary to refer to particular instances. If we descend from the hilly and mountainous regions, and examine the courses of our rivers near their entrance into any widely extended plains, we frequently find their banks composed of incoherent materials of a new character. They are not made up of thin layers of comminuted matter formed by successive inundations, or of silt and turf-bog accumulated in stagnant waters, but of great irregular masses of sand, loam, and coarse gravel, containing ~~through its mass~~ rounded blocks sometimes of enormous magnitude. It is at once evident that the propelling force of the rivers is entirely inadequate to the transport of such materials as these. We may observe, moreover, that they are not confined to the banks of the rivers, but spread over all the face of the country, and often appear at elevations many hundred feet above the level of any natural inundation. To such materials as these the term *diluvial* (indicating their formation by some great irregular inundation) is now applied by almost all the English school of geologists.

The rivers which descend from the western moors and unite in the great central plain of Yorkshire, afford a succession of beautiful illustrations of the appearances which have been just described. While rolling from the mountain chains, and uniting with their different tributary branches, they leave masses of alluvial matter in every place where the form of the valley admits of such a deposit: and after passing through the inferior region and escaping through many ravines and gorges into the great plain of the new red sandstone, they then find their way through enormous masses of *diluvial debris* which often mask the inferior strata through considerably extended tracts of country. If we follow any of these rivers into the central parts of the great plain, we may still find (with occasional interruptions) the *diluvial detritus* descending with the surface of the

ground, often forming the channel of the waters, and, where the level of the country admits of it, sometimes surmounted by an accumulation of newer *alluvial* materials. By the ordinary action of the waters, the two distinct classes of deposits sometimes become mixed and confounded; but I have never seen an example where their order is inverted, or where, through any extent of country, they alternate with each other. The instances adduced are not exceptions to, but examples of, the general rule. There is not, I believe, a single river in England which does not afford a more or less perfect illustration of some of the phenomena above described.

Perhaps the most important class of facts connected with *alluvial* phenomena, and which at the same time very strikingly exhibit their relation to all other deposits in this country, are to be met with in the low marshy regions near the mouths of some of our larger rivers. In proof of this assertion I shall proceed to describe some of the physical characters of the fenny tract of country which stretches from the south part of Lincolnshire to the base of the chalk hills of Norfolk, Suffolk, and Cambridgeshire. If a section be made through this region in a direction which is transverse to the outfall of the waters, its profile will be represented, first, by a line descending from the higher part of Lincolnshire to the level of the fens; secondly, by a succession of horizontal lines exhibiting the several levels of distinct fenny regions, interrupted here and there by extensive protuberances of *diluvial* gravel;* lastly, by an undulating line ascending from the *alluvial* region to the top of the hills which form its south-eastern boundary. If a section were made in a direction transverse to the former, commencing at the south-west boundary of the low lands, and ending in the sea, its profile would be represented, first, by a line showing the descent of the high lands to the level of the fens; secondly, by a long line extending almost at a *dead level* (except where it is interrupted by some of the protuberances above-mentioned) to the eastern extremity of the fens in the immediate vicinity of the coast; lastly, by a line *descending rapidly* from the level of the fens to low water mark.† The singular contour indicated by the second section has unquestionably arisen from the continued accumulation of *alluvial* silt which has choked up the mouths of the rivers, and raised their beds and all the contiguous country far above their ancient level.‡

* During great inundations these diluvial hills resemble islands rising out of an inland sea. Most of the towns and villages in the Isle of Ely are built upon them.

† Thus from Peterborough to Sutton Wash below Wisbeach (a distance of more than twenty miles), the fall of the water is on the average three inches and a half for each mile. But from Sutton Wash to low-water-mark at Crabhole, the fall is more than three feet for each mile.—(See Rennie's Report on the Drainage of the Bedford Level.)

‡ Thus Thorney north fen is thirteen feet; Peterborough low fen twelve feet six

It is not, however, the external contour so much as the internal structure of the district, which bears on the subject of this paper. The whole of the alluvial *delta* exhibits, as might be expected, a great uniformity in the arrangement of its constituent beds. When the vegetable coating is removed from any part of it, we may generally find below a brownish black earth which is formed of a variable mixture of common vegetable soil, of peat, and of alluvial silt. The different qualities of fen land arise out of the variable proportions of these constituents. In those tracts which are pent up between high artificial banks and upon which water frequently stagnates, the soil is almost exclusively composed of decayed vegetable matter converted more or less perfectly into the state of peat. In other more favoured tracts, more especially on the sloping skirts of the diluvial hills, the soil is of great fertility, and is composed principally of the accumulated silt of successive inundations. Materials possessing some of these characters are in many places accumulated upon the regular strata of the country to the thickness of nearly twenty feet. When they are laid bare by any artificial section, we may often see various modifications which are so far interesting as they throw light upon the ancient history of these deposits. In one part of such a section we may find the prevailing black earth interrupted by thin beds of peat, each of which indicates the temporary residence of stagnant water. In another part of the same section, the prevailing soil is seen to alternate with layers of sand and silt which mark the effects produced by extraordinary land floods. Alternations like these are so common as hardly to deserve any notice. If the section descend still further, we not unfrequently find the whole series of alluvial deposits separated from the true substratum (which in many places is composed of a stiff blue clay)* by a very thin bed of light coloured, unctuous, marly silt. This marly silt is, if I mistake not, of great antiquity, and must have been deposited by the waters prior to the existence of any portion of the alluvial covering.

If all the soil and accumulated *detritus* were removed from the district I am considering, it is certain that the surface of the ground would present many considerable irregularities. It is further evident that such a surface must in ancient times have

inches; Peterborough great fen thirteen feet two inches above the level which ought to form the base of the drainage near the sea.—(See Bower's Report of the New Drainage near Boston.)

* In all the central parts of the fens, the blue substratum contains innumerable specimens of the characteristic *gryphæa dilatata* of the Oxford clay; but near Ely, under the *alluvial* and *diluvial* detritus, there is a bed which contains the *ostrea deltoidea* of the Kimmeridge clay. If I mistake not, the coral-rag formation thins off before it reaches the fens, where the two clays are probably brought into immediate contact. Below Cambridge, the tracts of fen land rest on the galt or Folkstone clay.

supported many varieties of productions which are now so deeply buried as to be reached only by occasional artificial excavations. This remark at once explains the variable thickness of different portions of the fen lands, and the extraordinary appearances we sometimes meet with in digging through them. For example: in excavating the foundations of the new *lock* on the river Cam between Clay Hithe and Ely, they reached (after passing through ten or twelve feet of common fen soil) a bed of considerable thickness composed almost entirely of hazel wood and hazel nuts. The wood could not, I think, have been drifted from any great distance; and the enormous accumulation of nuts (many pecks of which might have been collected in the space of a few square yards) seemed to be the production of an ancient period when, year after year, the trees shed their fruit on the ground, and there were no inhabitants to collect it. In many other places, after passing through a thick coating of turf bog and alluvial silt, we meet with the branches, trunks, and even the roots of large timber trees. Some of these may have been floated down during great floods from the neighbouring high lands; but the far greater number of them have unquestionably grown near the spots where we now find them. Examples of this kind are, I believe, supplied by almost all the extensive fen regions in our island.

Lastly, I shall briefly notice a class of facts which, although admitting of a very easy explanation, have sometimes led to erroneous conclusions. In almost all the marsh lands which border on the sea, the *alluvium* is separated from the old subjacent strata by a quantity of marine silt, and sometimes by beds of sea shells which appear to have lived and died on the spot where they are now found. The extent of this marine deposit towards the interior of the country plainly indicates the extent to which the alluvial materials have been accumulated and pushed down within the ancient line of the sea coast. But the case is not always as simple as I have here stated it. The lower portion of the marsh lands in question sometimes exhibit several distinct alternations of marine silt and shells, with turf bog and other freshwater deposits. Facts of this kind were (if I have not been misinformed) observed in some of the lower parts of the Eau Brink cut which was lately completed in the neighbourhood of Lynn. We are not to suppose that such facts indicate any sudden change in the relative level of land and sea. All the alternations above described are below the level of high-water, and naturally result from the manner in which the fen lands have been formed. We have only to recollect that in the places alluded to, the tides have for many ages been ebbing and flowing along a system of planes which have been perpetually encroaching on the coast, and perpetually

changing their inclination. Of such a state of things, the occasional admixture of marine and freshwater deposits, and the occasional alternation is the inevitable consequence.*

Sect. 2.—*Diluvial Formations.*

It remains for me briefly to notice the diluvial formations which appear within the limits of the tract I have been describing. They seem to have been rapidly and irregularly accumulated by an inundation which acted with extrordinary violence; for they are partly composed of broken masses of more ancient strata, which are rounded and ground down by attrition, and which in many instances have been transported from distant parts of the country; and they contain no alternations indicating (as in the case of alluvial deposits) the *long continued and tranquil* operation of the agents by which they have been produced. They rest on the ancient strata of the country without the intervention of any other deposit whatsoever, and in instances without number they form the basis of the whole alluvial detritus.

The true relations of the *diluvial detritus* are beautifully exemplified on the flanks of the chalk hills which skirt the south-eastern side of the marsh lands above described. It is constantly seen to rest immediately on the fundamental rock; to follow all the irregularities of the surface; to rise out from beneath all the alluvial lands, and sometimes to lie in scattered masses on the very top of the chalk downs. From thence it may be traced, almost in a continuous mass, still further to the south-east, where it is heaped up to an enormous thickness, and overlies the newest *tertiary* beds which exist in that part of England. From all these facts we are justified in concluding, that the *diluvial* and *alluvial* deposits above described are not only essentially different in their structure, but belong to two distinct epochs; the former class of deposits having been produced by some extraordinary disturbing forces prior to the existence of any portion of the other class.

Were the order above given contradicted by the arrangements of the superficial deposits in other parts of our island, we should of course be prevented from drawing any general conclusion from it. But I believe there is no inconsistency in the order of our superficial deposits, and that the counterpart of the

* A fine instance of this kind of alternation may be seen in the lower Pentowan *stream-work* near St. Austle. The *diluvial tin ground* (which is nearly thirty feet below the level of high-water) is covered with a deposit (about seven feet thick) of compressed vegetable matter, leaves, roots, and trunks of trees, &c. all of which have evidently been drifted into their present position by floods, or perhaps by the *slide* of a half-formed turf bog. Over this deposit are a succession of marine beds (above twenty feet thick) obviously accumulated, while the lower part of the valley was an estuary. Lastly, a thick formation of peat, containing branches and trunks of trees, rises above the level of high-water, and is surmounted by common vegetable soil. For a detailed account of this section, see Geol. Trans. vol. iv. p. 404, &c.

facts above stated may be found in every country which is similarly circumstanced with that which has been described. My object is not, however, to make out a new arrangement, but to confirm an old one; I shall, therefore, content myself with referring to one additional class of examples.

In many parts of Cornwall the flanks of the central chain of hills are covered with a thick deposit of diluvial gravel, which, after resting immediately on the granitic and schistose rocks of the country, and following their inclination, often descends into the lower part of the transverse valleys, and from thence shelve down below the level of the sea. Near the mouths of these valleys the *diluvium* is always covered up by beds of a more recent *detritus* which in some places are nearly sixty feet thick. Notwithstanding their great thickness, many large excavations have been made through them for the purpose of extracting the tin ore which has been washed down from the mountains at the time the *diluvial* rubbish was formed, and which (in consequence of its great specific gravity) has naturally subsided to the bottom of the formation. In various excavations of this kind (provincially called stream-works), conducted in different parts of the county, we may see in the clearest manner the true relations of the several superficial deposits; and (as far as any thing can be proved by single instances) the sections show; first, that all the *diluvial detritus* in that part of England originated in the same system of causes which, having produced their effects once, were never repeated;* secondly, that all the *alluvial detritus*, of whatever kind, is posterior to the preceding; because it constantly rests upon it, and never alternates with it.

By the examination of facts like these, we become acquainted with the natural history of such superficial deposits as I have been describing. The facts are in strict accordance with every thing which I have myself observed, and they are, I believe, in accordance with the observations of all English geologists who have personally examined the evidence connected with this subject. We may therefore conclude on an induction founded on a very wide range of consistent observations; 1. That *alluvial deposits* include a large class of formations which have originated in causes such as are now in daily action; 2. That the same causes have acted during a long period; 3. That during that period the deposits have not been interrupted by any catastrophe which has interposed any other deposits of a distinct character; 4. That *diluvial deposits* possess a distinct character from the preceding class, never alternate with them, and, from their position, evidently belong to an older epoch; 5. That during the epoch in question, the *diluvial* gravel was produced by extraor-

* This fact is of great importance and was, I believe, first remarked by Townsend in his "Vindication of Moses." (See vol. i. p. 227, &c.) I had repeated opportunities of verifying this remark during a tour in Cornwall made in the summer of 1819.

dinary inundations; 6. That the disturbing forces which produced these inundations acted on the earth's surface after the deposition of all the regular strata with which we are acquainted.

The separation of the incoherent materials, which are heaped on the regular strata of the earth, into *diluvial* and *post-diluvial detritus*, is, therefore, a natural separation, which is at once descriptive of the things designated, and founded on the constant relations which they bear to each other. Moreover it is unconnected with any hypothesis whatsoever, and is independent of any argument drawn from the nature of the organic remains contained in different parts of the several deposits.

Sect. 3.—*Organic Remains in Alluvial Formations.*

I should not have dwelt so long in illustrating the preceding conclusions, had I not known that the nature of the evidence on which they are founded has often been entirely overlooked or misunderstood. In the next place, I shall briefly consider the organic remains contained in the two classes of deposits, especially in those localities which have been already described. The following specimens were derived from the *alluvial debris* which rests on the *diluvial tin ground* in various parts of Cornwall.

1. A human skull buried 36 feet in *alluvium*, from the Carnon *stream-work*. 2. Horn of an ox 40 feet deep in *alluvium*, from the same place. 3. Fragments of a human skeleton, from the Pentowan *stream-work*. 4. An ancient earthen vessel, formed without the potter's wheel, more than 40 feet deep in alluvium, and about 10 or 12 feet *above* the *diluvial tin ground*, from the same place. 5. Part of a culinary vessel buried 24 feet in *alluvium*, from the Levrean *stream-work*. A celt and some other rude works of art were found near the same place. To the preceding might be added a long list of spoils derived from the *alluvial* region which stretches out from the neighbourhood of Cambridge to the wolds of Lincolnshire, such as various specimens of trunks and branches of trees; of freshwater and land shells; of implements of human workmanship; of horns, teeth, and sometimes skeletons of animals which have been either drifted into the marshes, or have perished there by accident or violence, &c. &c. To which catalogue might be added, the skeletons of four beavers found near Chatteris in the *alluvial* bed of the Old West-water, a river which in former times performed an important part in the drainage of the country, but which has been choked up for 200 or 300 years.* We look in vain into these lists for the bones of the cavern-bear, the mam-

* See a paper by John Okes, Esq. in the Transactions of the Cambridge Philosophical Society, vol. i. p. 176.

moth, the hyæna, the rhinoceros, the hippopotamus, and other animals, the spoils of which are found in almost miraculous abundance in many parts of the world buried in the old *diluvial detritus*.

When we consider the great extent of the *alluvial* tract above described, and the various cuts and drains which have been made through almost every part of it: and when we further consider that the same tract of country is the growth and accumulation of at least 2000 or 3000 years; the negative argument becomes complete, and we conclude, almost with certainty, that during this long period not one of the several species of animals last enumerated existed in the neighbouring parts of our island. Let these considerations be combined with the admirable details and illustrations supplied in the writings of Cuvier and Buckland, and we readily extend the same conclusion to other parts of England, and indeed to every part of the world, which has been rigidly examined.

It may, however, be urged that no accumulation of negative evidence can stand against the direct evidence of opposing facts. Is then the preceding conclusion opposed by any incontrovertible facts? To such a question I should not hesitate to reply by a decided negative. Ambiguous cases may occur near the base of a crumbling sea cliff, or near the bank of a river which is continually falling down from being undermined by the attrition of the waters; or in the silt and alluvial rubbish of a valley which for many ages has been modified and ravaged by successive floods. In such situations the spoils of *alluvial* and *diluvial* deposits may be *mechanically mixed* together so as to render it impossible to separate them.

A sober-minded naturalist who makes his inductions after an extended examination of facts, and who does not view all things through the distorting medium of an hypothesis, will never derive from such localities as these any argument for the true arrangement of spoils found in different parts of the superficial gravel. The only way in which spoils derived from such situations can be classified, is by comparing them with similar remains found in other deposits, the relations of which are clearly exhibited, and which have been modified by no subsequent disturbing forces. Had this observation suggested itself to Dr. Fleming, he might have withheld more than half the examples he has brought forward in the Edinburgh Philosophical Journal (No. 22, p. 297, &c.) with a view of overturning the distinction which has been drawn between the organic remains of *alluvial* and *diluvial detritus*. In regard to the mammoth, he has not produced a single example of its remains found in undisturbed *alluvium*. Some of his examples may, perhaps, be ambiguous; but others are derived from localities which, had he taken the trouble to examine them himself, he would

have known to be *diluvial*. A single example is given of the bones of the hippopotamus found *under* a peat-bog. But the fact is given without details, and without the shadow of a proof that the bones were buried in *alluvium*. The case of the great fossil elk may perhaps be ambiguous. A gigantic animal of that family would soon be marked out for destruction; or it may perhaps have been exterminated by beasts of prey before the peopling of Western Europe. All the spoils of this creature which I have myself seen *in situ* do, however, belong to *diluvial* deposits. The three examples of horns of the rhinoceros found in *alluvial* marl-pits and turf-bogs, and preserved in the museum of Edinburgh, seem at first sight to throw most formidable difficulties in the way of the received classification. Through the kindness of Prof. Jameson, I have lately seen the specimens in question, and I know from the Professor himself that there is no adequate evidence to prove them genuine fossils. Without this information, from their look and their condition, I should not have hesitated a moment in rejecting them as spurious. It is contrary to my present object to enter into any details connected with the examples to which I have referred. I do, however, unhesitatingly assert, that as far as regards the purpose for which they were adduced, they are altogether without weight, and without importance.

Sect. 4.—*Organic Remains in Diluvial Detritus.*

The *diluvium* in the central parts of the fens of Cambridgeshire, or on the sides of the low hills by which the region is skirted, is found to possess a great uniformity of character. It contains innumerable fragments of gryphites, echinites, shells, corals, lizards' bones, and other fossils, all more or less perfectly mineralized, and all obviously torn up from the regular strata of the country by the same disturbing forces which formed the ancient gravel. Among these fragments, and among rounded blocks of stone chiefly derived from the same strata, are many minute fragments of bones, and sometimes entire teeth of various animals, more especially of the horse, the ox, the deer, and various graminivora. Among these, the remains of animals (such as the mammoth and the rhinoceros) now unknown as the inhabitants of any part of Europe are by no means uncommon. To describe, or even to enumerate, such specimens in detail would be foreign to my present purpose. I shall only refer, by way of example, to some of the organic spoils derived from the undisturbed *diluvium* in the neighbourhood of Cambridge. 1. Fragments of the pelvis of a mammoth, from the gravel south of St. Ives, Huntingdonshire. 2. Grinder of the mammoth, from the *diluvium* which stretches from St. Ives towards the centre of the fens. 3. Fragments of a large mammoth's tusk, from Foulmire. 4. A very large grinder of the mammoth, from the gravel

beds at Hinxton. 5. Innumerable fragments of the bones of various animals from the beds of small flint-gravel, north-west of Cambridge. 6. Eight or ten fragments of mammoth's grinders, from the thick gravel beds behind Barnwell. 7. Three or four large and perfect grinders of the mammoth, from the fine flint-gravel south of Cambridge; along with which were found several bones of the horse, and teeth of various graminivora. 8. Many teeth of various graminivora; humerus of a very large mammoth; several teeth of the rhinoceros; horns and portions of two enormous skulls of the urus or buffalo; an atlas (probably belonging to one of the preceding species), in linear dimensions about twice as large as the atlas of a full grown ox; several perfect bones of the horse; fragment of the horn of the *cervus giganteus;* &c. &c. all derived from the gravel beds at the north-west end of Barnwell.*

Such are the organic remains contained in a small part of the *diluvium* of this country; all of them differing in condition, and many of them differing in kind from the corresponding spoils of the *alluvial* beds of the same district; and the distinction is rendered still more complete by the fact, that not one work of human art, and not one fragment of a human skeleton, have yet been discovered in any part of the numberless excavations which are conducted in the lower and more ancient deposit. When we properly estimate these facts (which are but the counterpart of some of the admirable details given in the "Reliquiæ Diluvianæ"), and consider how very small a portion of the superficial gravel has yet been turned over even in the most populous parts of our island. We are compelled to admit that animals almost without number must have inhabited all the lower parts of Europe before the commencement of those destructive operations which produced the *diluvial* gravel.† A further examination of the facts already stated leads us also to conclude, that many pre-existing species of animals must have perished during the operation of the same destructive causes; because we do not find their remains in any more recent deposit.

It is in vain for any one to attack these conclusions by demanding how it came to pass that one class of animals perished during the formation of the diluvial gravel, and another class survived it. The same difficulty meets us in classing many of the regular strata of the earth. The suite of fossils derived from one formation may be widely different from the suite derived from another; yet we know by experience that both suites may contain many individuals of a common species.

* Most of the specimens from this locality are in the possession of J. Okes, Esq. of Cambridge.

† This conclusion had been completely demonstrated, in the opinion of most geologists, from the number, the nature, and the condition of the organic remains of the gravel: had any doubt remained on the subject, it is now set at rest by the details connected with the Kirkdale cavern given in the "Reliquiæ Diluvianæ."

Still less are the conclusions shaken by the hypothesis, that the weapons of the hunter completed the extinction of many species of animals, of whose former existence we have no knowledge, except through their bones, which are buried in the beds of old *diluvial* covering. From the only physical evidence which we can have on such a subject, we believe that not a single hunter had ever trodden in the woods of Europe at the time when the mammoth, the rhinoceros, and the hyæna were its inhabitants. And the records of Europe afford no proof that such beasts ever inhabited this part of the world in times within the reach of history. Again, we know by direct evidence, which is independent of any zoological details and of any history, that the diluvial gravel is of great antiquity; and we know from history that in ancient times large tracts of Europe existed in the form of unreclaimed marsh or almost impenetrable forest. Under such circumstances, are we to believe that a set of inhabitants, savage, almost naked, and few in number, should have waged a war of extermination with large and formidable beasts like the rhinoceros, the cavern-bear, and the hyæna? The hypothesis which attributes the extinction of such animals to the agency of hunters in the early ages of the world is at once gratuitous and incredible.

As the general result of all the preceding details, we may conclude that the separation of the superficial debris of the earth into two classes (*diluvial* and *post-diluvial detritus*), formed by different causes, and during distinct epochs, is completely made out; first, by the direct evidence of natural sections proving one formation superior to the other; secondly, by the distinct suites of organic remains imbedded in the two deposits. The lower formation containing many organic remains which are never found in the upper; and the upper also containing many which are not found in the lower. In these respects, perhaps, no two contiguous formations in the crust of the earth are separated from each other by more clear and decisive characters.

Sect. 5.—*On the Causes of Diluvial and Alluvial Phenomena.*

The conclusions which I have attempted to vindicate in the preceding sections, however interesting in themselves, give us but scanty means of speculating on the causes which have produced the *diluvial* deposits. It may be asked, by what forces were the diluvian torrents first put in motion? In what direction did they sweep over the earth? On what part of the earth's surface have they acted? Did they operate almost simultaneously over all parts of the world, or did they act at intervals and during a long period of time? What was the condition of the globe prior to their action, and what are the modifications in its external character produced by them? To some of these questions, no answer can be given, and to none of them can we give

a complete answer in the present state of our information. If, however, a great many well observed facts seem to point to one conclusion, that conclusion must be considered probable until it is opposed by some other conflicting facts. One thing at least is certain, that no hypothesis can be admitted which is not borne out by that series of facts (however imperfect) with which we are now acquainted.

On these grounds I do not hesitate a moment in rejecting the hypothesis which allows the formation of *alluvial* deposits in the manner above described, but accounts for all the *diluvial* phenomena by a succession of partial and transient inundations, occasioned by the bursting of lakes, and other similar catastrophes.* In the first place, the cause assigned is inadequate to the effects produced. The physical contour and structure of the central and southern parts of England show the impossibility of any large lakes ever having existed among our secondary strata, capable of producing the enormous and almost continuous beds of gravel which stretch along the eastern coast. Several striking facts connected with this question have fallen under my own observation; and, as far as they go, confirm the general views given in the "Reliquiæ Diluvianæ." As the description of these facts will lead me into some details, I hope to resume the subject in the next number of the *Annals of Philosophy*. Secondly, the hypothesis is gratuitous. In many parts of England, where there is abundance of superficial gravel, there is not the shadow of evidence to prove that any great body of water was ever pent up among the neighbouring strata, so as to form a lake which afterwards burst the barriers by which it was confined. Catastrophes of this kind sometimes happen in mountainous regions, and the effects produced are commensurate to the agents; but these effects have nothing to do with the great masses of superficial gravel even in the contiguous districts.† Thirdly, the feeble agents which the hypothesis allows would require an indefinite extension of time before they could produce such effects as the earth's surface plainly exhibits. But the quantity of marsh land and silt formed at the head of many lakes, the extent of different deltas, and other similar phenomena, appear to demonstrate that all *alluvial* deposits have been completed within a very limited period.‡ The hypothesis is, therefore, inadmissible, which makes *alluvial* and *diluvial* deposits contemporaneous, and implies an indefinite period of

* This appears nearly to agree with Saussure's opinions, and is still held by some geologists on the Continent.

† In consequence of the prevalence of local disturbing forces, such as those alluded to in the text, the great relations of the superficial *detritus* cannot be studied to so much advantage in the immediate neighbourhood of mountain chains, as in the lower regions of the earth's surface.

‡ We owe this conclusion to Deluc who devoted the labours of many years to its confirmation. Had his labours terminated here, he had done great service to geology.

time for their formation. Fourthly, the hypothesis does not account for the different suites of organic remains found in each deposit. Lastly, it does not account for the constant order in the position of *alluvial* and *diluvial debris*. Had they been formed in the way which the hypothesis implies, they must sometimes have alternated. Each of these objections might be expanded and illustrated by many details; but to enter on them would be foreign to my present purpose.

The details already given in the preceding sections sufficiently explain the origin of common *alluvial* formations. But there are two classes of phenomena exhibited on several parts of the coast of our island, which are intimately connected with the present inquiries, and do not always admit of easy explanation, viz. 1. Traces of recent marine deposits above the level of high-water. 2. Extensive traces of ancient forests in situations which are constantly overflown at high-water.

Phenomena of the first class are generally met with on the banks of estuaries where the waters of the sea necessarily undergo great oscillations. By the extraordinary combination of a high spring tide, and a hurricane blowing in the direction of the current, whales and other marine animals have from time to time been stranded on the banks of estuaries in situations 20 or 30 feet above the reach of common floods.* This is not mere hypothesis: we know that by the combination of such circumstances as these, the sea has two or three times, within the last 600 years, risen to an extraordinary elevation on the coast of Holland, and overwhelmed large and populous tracts of that country.

The existence of *submarine* forests is not so readily accounted for. Some writers have supposed them to be the effects of earthquakes, which in ancient times have submerged large tracts of forest land bordering on the sea coast. Without pretending to exclude such agents in cases which without them admit of no explanation, I think that in a vast majority of instances it is unnecessary to introduce them. The mean elevation of the sea about every part of our coast is unquestionably constant; but the actual level of high-water at any given place is dependent on the velocity and direction of the tidal currents, the contour of the coast, and a number of circumstances which are entirely local. In proof of this assertion, it is only necessary to appeal to the fact, that in extensive bays and estuaries, the sides of which gradually diverge towards the open sea, the tides occasionally rise (through the operation of a common hydrostatical

* Two examples of this kind are noticed by Dr. Fleming in the last number of the Edinburgh Philosophical Journal, p. 124. Such cases must be carefully distinguished from all tertiary deposits; and from such accumulations of marine shells as are seen in the *crag-pits* on various parts of Norfolk, Suffolk, and Essex. These latter instances unquestionably belong to no natural marine inundation, and are, at least, as old as the *diluvium* in that part of England.

law) to an elevation which is many times greater than the rise of the same tides on more open parts of the coast. Any set of causes which greatly modify the form of a deeply indented coast, must, therefore, inevitably produce considerable local effects upon the level of high-water.

Let these remarks be applied to the eastern shores of England. We know that during the last 1000 years, the sea has made enormous encroachments on many parts of Suffolk, Norfolk, Lincolnshire, and Yorkshire; not only modifying the whole contour of the coast, but at the same time forming chains of shoals and sandbanks by which the velocity and the direction of the tidal currents must have been more or less affected. The waters have, therefore, during successive ages, been propelled into the recesses of the coast by different forces, and up different systems of inclined planes; and must in consequence have ascended to different levels. Such effects as these will reach their maximum on the shores of large bays and estuaries, like the Humber and the Wash of Lincolnshire.

The form of the Wash of Lincolnshire must have been greatly changed since the epoch of the *diluvial detritus*, partly by the degradation of the neighbouring cliffs; but still more by the encroachments of *alluvial* silt which has been pushed down into it by the waters of the Witham, the Glen, the Welland, the Nene, and the Ouse.* If an undulating line be drawn through these several rivers a few miles above the estuaries in which they terminate, it may be taken as an approximation to the form of a part of the coast in very ancient times before the great accumulation of *alluvial* matter. The country within this line then presented a low undulating surface, gradually rising on every side of the Wash towards the high lands; and it was probably almost covered with forest trees, with the exception of a few very low regions through which the rivers descended to the sea, and which were partially flooded at the time of high-water. But in the present state of things, the flood-tides, after filling the lower part of the Wash, are pushed on towards the ancient line of coast through a number of estuaries, the sides of which converge towards the interior, and on that account force the waters up to a higher level than they could reach on a coast which was less indented. And after the flood-tides have been thus pushed up into the mouths of the rivers, they do not now, as in former times, mix with the freshwater and cause a reflux, extending far into the interior of the country; but after rising, almost at once, to a high level,† they are pent up between artificial banks, and soon stopped altogether by *locks* and other works connected

* A long note containing some details connected with the drainage of the fens bordering on the Wash, arrived too late for the press, but will be affixed to the *continuation* of this paper.—*Edit.*

† See note 2, p. 6.

with the artificial drainage and navigation of the country. It is almost certain that in such a state of things the tides cannot rise to the exact level which they reached in ancient times ; and the change will, I think, be precisely of that kind which will explain the appearance of submarine forests in many places bordering upon the Wash. If through a combination of causes such as have been mentioned, the tides on any part of the coast rise to a level only a few feet higher than they did in ancient times, the whole difficulty we have been considering at once vanishes.

The conclusions which have been deduced from a consideration of certain facts exhibited on the coast of Lincolnshire, may be extended to every country which is similarly circumstanced; and it seems probable that an actual change in the height of the tides produced by a change in the contour of the neighbouring coasts, is among the most general and efficient causes which have produced the phenomena of submarine forests. By this assertion it is, of course, never intended to exclude other agents from their proper share in producing the phenomenon. Forest trees may have grown in many low tracts bordering on the sea while they have been protected from the flood-tides by artificial, and sometimes, perhaps, by natural embankments ; and in subsequent ages the embankments may have failed, and the forests may have been submerged by a consequent incursion of the waters. Fen lands, after being drained and brought under cultivation, may have undergone a natural subsidence, and on that account have been exposed to the chance of subsequent inundations. This at least was Deluc's opinion, founded on observations made in various parts of Holland. Lastly, large tracts of low alluvial land may (after the natural destruction of the barriers by which they were held in) be transferred by a slide to a lower level ; and in that way productions once out of the reach of the high tides may become exposed to their constant attacks. By the gradual operation of such causes as have been enumerated, the existence of submarine forests may in most instances be satisfactorily explained without the intervention of earthquakes or other irregular disturbing forces.

The phenomena above described (viz. the existence of land productions below, and of marine productions above the level of high-water) are after all things *sui generis*, which are confined to a small part of the coast; and, however interesting in themselves, throw no light whatever on the general classification of *alluvial* and *diluvial* deposits.

(*To be continued.*)

On Diluvial Formations. By Professor Sedgwick.

(To the Editors of the *Annals of Philosophy*.)

GENTLEMEN, *Trinity College, Cambridge, May,* 1825.

The following remarks on certain *diluvial deposits* form a supplement to a paper which you did me the honour to publish in the *Annals of Philosophy* for the month of April. Circumstances, over which I have had no control, have prevented me from resuming the subject sooner; but I venture to hope that the statements which are now offered for insertion in your journal, will be found sufficient to explain and vindicate the opinions advanced in my former communication.

I have the honour to be, Gentlemen,
Your most faithful servant,
A. Sedgwick.

Separation of Alluvial and Diluvial Formations.

In my former paper on the origin of *alluvial* and *diluvial* formations, I endeavoured to explain the nature of the evidence on which the two classes of deposits had been separated from each other; and I also endeavoured to show, that diluvial formations have not originated in a succession of partial and transient inundations occasioned by the bursting of lakes, or by the *ordinary* operation of any cause with which we are acquainted. The last conclusion might, perhaps, be established by showing the constant order in the position of the two deposits, and the different suites of organic remains contained in them. It derives, however, its most direct support from the two following considerations: 1. That, with very limited exceptions, the earth's surface exhibits no traces of ancient lakes capable of producing any portion of the superficial gravel. 2 That admitting

(although against direct evidence) the existence of such ancient lakes, we shall not, by that hypothesis, introduce an agent capable of producing the *diluvial debris* which is exhibited on almost every part of the earth's surface which has been well examined.

In illustration of the first of these two assertions, I need only state, after Prof. Buckland, that in none of the higher parts of England out of the reach of ordinary floods, have any traces been yet discovered of lacustrine terraces, such as those which are seen in one or two of the glens of Scotland, or of any other deposits indicating the former presence of extensive tracts of stagnant water. The hypothesis which ascribes the distribution of the enormous masses of diluvial gravel existing in so many parts of our island to the agency of a series of lakes, which from time to time have burst their barriers and descended to lower levels, may, therefore, at once be rejected as gratuitous.

Diluvian Action proved from the Form of many Valleys of Denudation.

There is another independent reason for rejecting the hypothesis, which may be properly stated in this place. That most of our secondary valleys have been formed by denudation, and that by the action of water many portions of the earth's surface have been greatly changed in form since the solid strata assumed their present elevation is universally admitted; the only question is respecting the manner in which such changes have been brought about. Now we may venture to assert, that in numberless instances the present drainage of the earth's surface could never have been effected, either by the long continued erosion of the elements, or by the bursting of any series of lakes once pent up among its higher regions; and if this statement be true, the present modifications in the external contour of the earth must have been effected by the action of water put in motion by powers which differ altogether with those with which we are acquainted. It is impossible in this place to enter on a detailed proof of the preceding assertion. By way of illustration, I shall only refer to two examples of the kind alluded to, though many others equally decisive of the question at issue, might be derived from various parts of our island.*

Wealds of Kent.

The first example to which I shall refer is supplied by the

* Some excellent observations connected with this subject may be found in the "Geological Survey of the Yorkshire Coast;" by Young and Bird, p. 279, 286. Many valleys appear to have been formed by an actual disruption of the strata produced at the time of their first elevation. Valleys of this kind are of course excepted from the remarks in the text, which apply exclusively to true valleys of denudation, such as those by which the greater part of the secondary strata of England are intersected.

natural drainage of a portion of the counties of Kent and Sussex. A number of small rivers take their rise in the central ridge of the Hastings sands (see Greenough's Geological Map of England), and descend from thence both on the north and south side into the longitudinal valleys occupied by the weald clay. Instead of finding their way to the sea through these valleys, the rivers proceed in a direction nearly transverse to them, and escape on the one side into the Thames, and on the other side into the Channel, by deep gorges cut through the escarpments of the North and South Downs.* In this way the whole region is intersected by a double system of valleys communicating with the sea, and crossing each other nearly at right angles. It is, I think, physically impossible that this singular contour should have been produced by the long continued erosion of the waters. For allowing that the rivers have scoured out the longitudinal valleys of the weald clay, no reason can be given why they should not flow down those valleys at this moment; and on this supposition it is inconceivable how they should ever have forced their way (in no less than eight places) through the high ridges of the North and South Downs. Again, if we suppose that the North and South Downs were once prolonged to the south-east so as to form a continuous ridge, we may shift the difficulty, but we shall not explain it. On this supposition a large inland lake might have occupied the region of the weald clay, and such a lake might have burst the chalk barrier, and formed one or two valleys of denudation. But it is impossible that such an agent should ever have formed the complex system of valleys by which the Downs are now intersected. That all these valleys have been opened out by the same disturbing forces which have produced the accumulations of superficial gravel in the neighbouring parts of England cannot admit of doubt. Yet we have the clearest physical evidence that the drainage could never have been effected by the ordinary operations of any of those disturbing forces which are now acting on the surface of the earth.

Drainage of the Isle of Wight.

The next example is supplied by the drainage of the Isle of Wight.† Two small rivers which rise on the south side of the central Downs might have escaped into the sea by low and direct channels cut through the incoherent ferruginous sands. Instead of this, they flow into the north channel, at Cowes and Brading, through two deep valleys which have been scooped out of the central chalk ridge. It is physically impossible that the rivers should have effected this passage for themselves. And if we suppose these valleys to be closed, it is incompatible with every

* See the "Outlines of the Geology of England and Wales," p. 145.

† See the map accompanying Dr. Fitton's paper published in the *Annals of Philosophy* for Nov. 1824.

thing we know of the structure of the country to conceive the existence of any lake whatsoever, much less of any body of waters capable of bursting through the high chalk downs, and of bringing the island into its present form. We are, therefore, compelled to admit, that the island has been reduced to its present form by some more powerful cause than any which is in ordinary action. A detailed examination of the surface of the country fully establishes this inference. For we have the most direct evidence to prove, that diluvian torrents have swept over every part of the Isle of Wight, its highest as well as its lowest elevations; and that they have scooped out deep valleys, and driven before them enormous masses of gravel, which are heaped upon the *upper freshwater beds* and all the other *tertiary* deposits which extend to the north channel.

Resulting Conclusions.

From a consideration of such facts as these, we may, I think, unequivocally establish the two following conclusions: 1. That during a period of time posterior to the deposition of the newest regular strata which are known to geologists, many parts of our island have been ravaged by powerful denuding forces. 2. That the form and direction of the valleys produced by these denuding forces, cannot be accounted for by any known action of the waters which are now draining off the surface of the country. On similar grounds the preceding conclusions might be extended to many other parts of the world; and they are obviously independent of any arguments drawn from the extent and the position of the *diluvial detritus*.

Position and Extent of the Diluvial Detritus.

In the remaining part of this paper I shall proceed to an examination of the materials which have been torn up by *diluvian* currents, and scattered over different parts of our island; and from the position and extent of these materials, I shall endeavour to prove that they cannot be accounted for by the ordinary operation of any known physical agent. It is not, however, my intention to enter on any general details connected with the history of this *detritus*, as they would inevitably lead me into ground which is already occupied by the author of the "*Reliquiæ Diluvianæ*." I shall, therefore, only select from the facts which have come under my own observation, two or three which seem to bear more immediately on my present object. On this account I forbear to notice the successive valleys of denudation, and the almost continuous masses of *diluvium* which present themselves on the south coast; and for the same reason I pass over all the corresponding phenomena in the central and southern parts of our island. I may, however, express a conviction, founded on a very extensive range of observations, that there is

not a single spot in the abovementioned parts of England which has been exempted from the attacks of those destructive forces which have produced the diluvial gravel. Whatever, therefore, may have been the origin of the phenomena in question, they are due to the operation of no partial or local agents.

Diluvium on the East Coast, &c.

1. The eastern parts of England from the chalk downs of Lincolnshire to those of Cambridgeshire, offer a series of striking facts connected with the history of diluvial phenomena. In the neighbourhood of Cambridge (and I believe also along the whole escarpment of the chalk in the counties of Norfolk and Suffolk), the diluvial deposits may be divided into two distinct classes. The first, composed of coarse materials, often lodged at considerable elevations, and apparently drifted into their present situation by the first rush of the waters: the second, generally found in lower elevations, and apparently comminuted by the continued attrition of the retiring waters. The extensive deposits of transported materials in the low region between Cambridge and Lynn, generally belong to the latter class; and the immense abundance of rolled flints contained in them seem to prove that the neighbouring chalk strata must once have extended considerably to the west of their present limits. An examination of the chalk downs themselves completely demonstrates that the denuding currents have not been confined to the lower part of the escarpments; but have pushed enormous masses of gravel over the very top of the downs, and have modified the whole surface of the district. Lastly, the bluff escarpment presented by the chalk on the coast of Norfolk, and the re-appearance of the same rock in the wolds of Lincolnshire, almost compel us to admit that the formation was once continuous, and that the whole Wash of Lincolnshire has been caused by denudation Be this as it may, we may conclude with certainty that the present form of the chalk downs of Suffolk, Norfolk, and Cambridgeshire, could never have been produced by any known action of the waters which now drain off that part of England; and the nature and position of transported materials, which the denuding currents have drifted over many parts of the neighbouring region, lead us to exactly the same conclusion.

Diluvium of Huntingdonshire and Cambridgeshire.

The elevated plains, which extend on the confines of Bedfordshire, Cambridgeshire, and Huntingdonshire, exhibit several partial deposits of such transported materials, from which the Rev. J. Plumptre, of Great Gransden, has selected a vast variety of rolled masses derived from almost every known formation in England. His highly interesting collection, obtained from the *diluvium* in the neighbouring district, may be divided into the

following classes:—1. Containing many ancient rocks derived from doubtful or unknown localities. 2. Many primitive and transition rocks resembling those existing *in situ* on the western side of our island. Some of these which are much rounded have probably, by an ancient catastrophe, been buried in the conglomerates of the new red sandstone; and afterwards, by the last catastrophe which has desolated the earth's surface, been transported into their present situation. 3. A fine series of specimens of mountain limestone and trap resembling the corresponding rocks of Derbyshire and Staffordshire. 4. An immense number of blocks drifted from the more recent strata. Out of this class one might select a good series of specimens characteristic of all the strata of England from the lias to the chalk.

Extensive deposits of diluvial rubbish similar to those last described occur in two or three places to the east and south-east of Cambridge. From the gravel on the top of the Gogmagog hills, I have found rolled masses of granite and porphyry; pebbles resembling those imbedded in the new red sandstone; masses of trap and mountain limestone; and a fine series of specimens derived from the oolitic formations. Masses of gravel of a nearly identical character lie scattered over several parts of the downs of Suffolk and Norfolk.* We must not imagine that the instances here given are indications of mere local operations. The gravel about Cambridge not only agrees in general character, but almost forms a continuous mass with the beds of gravel which are spread over many parts of the counties of Bedfordshire, Huntingdonshire, and Northamptonshire. And the patches of coarse diluvium which are scattered over the downs, are connected with a series of operations which have buried nearly the whole county of Norfolk and the greater part of the county of Suffolk under enormous masses of *diluvial debris*. Effects such as these are utterly beyond the reach of any known natural agent.

Plains of Cheshire and Derbyshire Hills, &c.

II. I intentionally pass over all details connected with the history of the transported materials in the great plain of the new red sandstone, and shall content myself with stating, that enormous masses of diluvium extend from the base of the great oolitic terrace through many parts of Leicestershire and Staffordshire, and through almost every part of the plains of Cheshire. The diluvial wreck of this region is found at all levels, for it is seen on the upper part of Charnwood forest as well as in the neighbouring vallies; and transported bowlders of considerable magnitude occur at the very top of several parts of the

* For some further details connected with this subject, see Prof. Hailstone's paper in the Geol. Transac. vol. iii. p. 244.

Derbyshire chain which overhangs the great plain of Cheshire. For example, many large smooth bowlders of primitive or transition rocks lie scattered over the surface of the ground on both sides of the high pass leading from Buxton to Macclesfield. These facts speak the same language with those which I have already quoted. They show the generality of the causes which have produced the superficial *detritus;* and they prove that their operations have not been confined to the lower parts of our island.

Western Moors, Central Plains, and East Coast of Yorkshire.

III. In my former paper I briefly noticed the great accumulation of coarse gravel on the plains which skirt the western moors of Yorkshire. Had this gravel been formed by a number of lakes which were once pent up among the mountains, and afterwards burst their way into the lower regions of the district, we might expect to find traces of such lakes in the interior of the moorlands, and distinct heaps of gravel marking the devastations produced by the discharge of the successive lakes into the plain of the new red sandstone. We, however, find no indications of such lakes; and the diluvial rubbish is spread out almost uniformly over the central plain by some cause which appears to have acted simultaneously, and which has left traces of its operation from the southern extremity of Yorkshire to the mouth of the Tees.

Every part of the Yorkshire coast and whole neighbouring region bear witness to the operation of similar causes. The numberless valleys of denudation in the eastern moorlands—the immense accumulation of transported materials on the hills as well as in the valleys—the whole contour of the vale of Pickering—the enormous cap of diluvium containing rounded masses of primitive rocks many tons weight, and resting on the chalk hills near Flamborough Head—the external form of the Wolds—and the continuous mass of *diluvium* extending from Bridlington to Spurn Head, and from the chalk downs to the sea, are so many monuments of the gigantic powers which were let loose upon the world during the epoch of the diluvial gravel. In the summer of 1821, I had an opportunity of examining all these phenomena in detail; and I can bear unqualified testimony to the faithfulness of the descriptions given of them by the author of the "*Reliquiæ Diluvianæ.*"*

The *diluvium* of Holderness is of great interest, partly from its immediate connexion with a series of operations which have affected all the neighbouring districts; partly also from its occupying the whole line of coast, and from its enormous thickness, which enable us to examine with detail all the circumstances

* See the "*Reliquiæ Diluvianæ*," p. 191, 194.

appearing to throw light upon its history. In many places where it occupies a succession of lofty cliffs, it puts on a rude appearance of stratification, or at least may be subdivided into separate masses which possess distinct characters.

The lower part of the cliffs, to the height of about twenty feet, generally consists of a stiff bluish clay, which in many places passes into a dark brown coloured loam.* Through the whole of this mass are imbedded an incredible number of smooth round blocks of granite, gneiss, greenstone, mica slate, &c. &c. resembling none of the rocks of England, but resembling specimens derived from various parts of the great Scandinavian chain. Irregularly mixed with the preceding are found, in perhaps still greater abundance, fragments of carboniferous limestone, of millstone grit, of lias, of oolite, and of chalk, torn up from the regular strata of the country, and driven into their present situation by a great eastern current which has left its traces on every part of the neighbouring district. In regard to the imbedded fragments above-mentioned, two things appear to deserve notice. 1. They exist in equal abundance in the upper as well as in the lower portions of the diluvial loam. This fact, though difficult of explanation, has been remarked in other similar deposits, and seems to prove the gigantic nature of the forces by which the materials have been drifted into their present position. 2. The bowlders derived from distant countries are rounded by attrition; but those which are derived from neighbouring rocks are little altered in form. The hard Norwegian rocks are smooth and spheroidal, but the fragments of oolite and lias, and still more the fragments of chalk, are often sharp and angular.

Over the preceding deposit come a set of beds of sand and comminuted gravel, very variable both in their structure and in their thickness. They seem to have been formed by a longer continued and a less violent action than that which produced the diluvial loam on which they rest.†

Over the sand and gravel we may sometimes find traces of ancient turf-bogs and of other alluvial deposits, formed in situations which were once in the interior of the country; but are brought into their present position by the encroachments of the coast.

* Large grinders of the mammoth have been found in several parts of this deposit.

† Near Bridlington there is a diluvial covering about sixty feet thick where we may observe, 1. The clay and loam with large imbedded fragments; 2. The sand and fine gravel; 3. Over the two preceding, and immediately under the vegetable soil, a bed composed of rolled fragments of chalk and of chalk flints; in some places cemented together so as to form a hard conglomerate. This bed is diluvial, and must be ascribed to the last action of the retiring waters. It may be traced to a considerable height on some parts of the downs ~~when~~ where it rests immediately on the chalk; and following the inclination of the ground, it descends towards, and at length covers, the ordinary diluvial deposits abovementioned.

Lastly, over all the preceding we find in many places a considerable thickness of blown sand.

Such are the phenomena exhibited in the cliffs of Holderness.

The masses of transported materials on the top of the Wolds, and still more the enormous masses which, on many parts of the coast between Filey Bridge and Redcar, are piled upon the regular strata to the thickness of 150 feet, admit of the same general subdivisions as the *diluvium* of Holderness, and undoubtedly belong to the same epoch. As we advance towards the north, the fragments of chalk begin to disappear; and fragments of magnesian limestone and of other rocks derived from the county of Durham begin to be more abundant

Conclusions.

The following conclusions may, I think, be fairly deduced from the facts above stated. 1. The *diluvium* of Holderness and of the whole east coast of Yorkshire, is due to a set of causes which have acted over the western moors, and over all the great central plain of the county. 2. The diluvial currents which produced the gravel of Holderness were probably contemporaneous with other more powerful currents which drove large masses of primitive rocks from Scandinavia to the plains of Yorkshire. And it seems probable that the same currents were contemporaneous with those mighty propelling forces which have driven innumerable fragments of the Scandinavian rocks over the great plains of Russia, Poland, and Germany.

Diluvium at the Base of the Cumberland Mountains, &c. &c.

IV. During the three last years, I have examined every part of the great cluster of mountains which is bounded by the valleys of the Lune and the Eden, and by the western coast from Moricambe Bay to Solway Firth. On its eastern side, this region is united with the great central chain of England; but on all other sides through three-fourths of its circumference, it is skirted by a succession of plains, or lands of low elevation, which are almost entirely buried under accumulations of diluvial matter. From the foot of Stainmoor to Solway Firth, through the whole plain of the new red sandstone, the incoherent materials under the vegetable soil are spread over the greater part of the surface, and are often of such an enormous thickness as entirely to conceal all the subjacent strata. These accumulations are not partial or irregular; but seem to have been rolled out over the surface of the country by an inundation which acted at one moment over the whole district; and like all similar deposits, they contain an incredible number of large bowlders, principally derived from the neighbouring mountains.

On approaching that part of the plain which borders on the northern extremity of the hilly region, we meet with pebbles and

bowlders which have been drifted across the Firth from the rocks of Dumfriesshire; and in the *diluvium* still further to the south-west, near the termination of the new red sandstone at Maryport, the imbedded fragments of the transition rocks of Cumberland become rare in comparison with the bowlders derived from the opposite coast of Scotland. In the diluvial rubbish capping a hill near Hayton Castle, about four miles north-east of Maryport, I found some large granitic bowlders resembling the rocks of the Criffel. Among them was one spheroidal mass, the greatest diameter of which was ten feet and a half long, and the part which appeared above the ground was more than four feet high.

From Maryport to St. Bees Head, the cliffs are occupied by a succession of coal strata; and the diluvial phenomena, though of constant occurrence, present nothing worth remarking in this place.

West Coast of Cumberland.

From St. Bees Head to the southern extremity of Cumberland, the region bordering on the coast is formed of one almost continuous mass of *diluvium*, interrupted here and there by low hills of blown sand, and by other recent formations. In this part of the county, the cliffs are of a deep red colour, caused by the presence of innumerable imbedded fragments of the subjacent new red sandstone. With these fragments, bowlders of granite, porphyry, and greenstone, are scattered through the whole diluvial covering; sometimes in such abundance as to give it the appearance of a true conglomerate; especially in places where, by the infiltration of a new cementing principle, the whole mass has begun to assume a coherent form.*

Some of the granite blocks imbedded in the cliffs are of great magnitude. In the diluvial cliffs near Bootle, I found one of a rude prismatic form which was twelve feet long, six feet wide, and five feet and a half high. All specimens of this kind of rock have been drifted to the coast from the granitic region which extends from Wastdale foot, through Muncaster fell to the neighbourhood of Bootle; and occupies a part of Wastdale Head, and all the lower parts of the valleys of the Mite and the Esk.

Diluvium of Low Furness.

If we cross the estuary of the Duddon to the shores of Low Furness, we find an exact repetition of the phenomena we have

* When these diluvial conglomerates are not seen *in situ*, they may be separated from the older conglomerates by the freshness of their imbedded pebbles. Fragments imbedded in the older conglomerates are generally in a state of decomposition, which appears frequently to originate in a similar cause to that which so often produces decomposition in crystals after they have become coated over by a deposition of newer crystalline matter.

left behind. All the country bordering on the western shore is covered by an enormously thick deposit of red coloured diluvial gravel containing innumerable rolled fragments of rocks derived from every part of the lake mountains; and all the neighbouring islands are composed exclusively of the same materials. A rolled mass of Eskdale granite, which had been imbedded in the highest portion of the diluvial cliff near Rampside, fell down upon the strand in the year 1822. It rose nine or ten feet above the rubbish in which it was at that time partially buried. At the base of the cliffs of the isles of Barrow and Foudrey, among innumerable bowlders of granite, and of other Cumberland rocks, were some specimens of a beautiful variety of compact felspar which I afterwards found *in situ* near the top of Sca-fell and Bow-fell.*

In places where the inferior strata are so completely concealed it is impossible to ascertain the whole thickness of the diluvial covering. In many parts of Low Furness, it must, I think, be considerably more than 100 feet. Near Newbiggin, where they were searching for coal in the year 1822, they passed through 60 feet of diluvial loam before they reached any rock *in situ*.

The phenomena above described have obviously been caused by a violent rush of descending waters. Whatever forces may have put these waters in motion, it is, I think, obvious, from the facts already stated, that they have not acted partially, but have swept over the whole cluster of the neighbouring mountains.

Diluvial Deposits in the Mid Region of the Mountains, &c.

V. If the accumulations of diluvial gravel, such as have been last described, were produced by descending currents which brought fragments of rock down from the very crests of the neighbouring mountains; we may expect to find some traces of such currents in the mid regions of the district between the highest elevations and the surrounding plains. In such situations, for obvious reasons, we must not look for those accumulations of diluvial loam which are extended over the lower country. The transported materials will only find a partial lodgment, or will appear in the form of scattered bowlders which the propel-

* The direction in which the diluvian currents have swept over the western coast of Cumberland, is plainly indicated by the immense accumulations of bowlders of Eskdale granite in Low Furness, and in the whole cluster of the neighbouring islands, and would lead us to expect the appearance of rolled masses of the same variety of rock on the plains of Lancashire. Prof. Buckland states (Reliquiæ Diluvianæ, p. 199), that they have been drifted in great numbers over the plains of Lancashire, Cheshire, and Staffordshire. In a description given by Dr. Hibbert, in the Edinburgh Journal of Science for last April, of an interesting diluvial deposit containing granite bowlders which occurs near Manchester, it is conjectured that the transported blocks are derived from the granite of Dufton near Appleby. Had the author been acquainted with the facts detailed above, he would probably have referred the bowlders in question to the Eskdale granite.

ling currents have left behind. Such is the case in the mid region of the lake mountains, where innumerable scattered bowlders give the clearest indications of the force and of the direction of the torrents which have swept over it. Any thing like a regular history of such phenomena would lead me into endless details. One or two facts bearing upon the subject will be enough for my present purpose.

1. On the granitic hills which extend from Bootle into Eskdale are many large bowlders derived from various parts of the green slate formation. Among the rest are some specimens of a striped hornstone, identical with the rocks immediately under the crest of Sca-fell, the highest mountain in Cumberland. These blocks are at present separated from the parent rock by the deep valley of the Esk.

Carrock Bowlders.

2. Millions of large bowlders lie scattered over the hills which form the north-west boundary of the mountainous region; but they are seldom sufficiently characteristic to enable us to determine the exact spot from which they have descended. The syenitic blocks of Carrock-fell, principally composed of hypersthene and compact felspar, may, however, be traced from the diluvial loam and gravel of the plains, through the valleys and over the hills of the mid region, to the very foot of the parent rock. On the side of High Pike (near the path leading from Nether-row to the lead mines) are innumerable bowlders of the Carrock syenite. The largest (which is known in the country by the name of golden rock) is 21 feet long, more than ten feet high, and about nine feet wide. The back of Carrock, where the same kind of rock exists *in situ*, is about two miles distant from the great bowlder, and is at present separated from it by a deep valley.

3. Rolled masses of the porphyry of St. John's vale almost cover the ground near Penruddock, and from thence follow the course of the valleys of denudation which descend into the Eamont. Blocks derived from a dyke of beautiful red porphyry which traverses a part of the ridge to the west of Thirlmere, are found scattered about on the lower part of the hills near Keswick.

Shap Granite.

4. Spherical bowlders of shap granite occur in great abundance on the calcareous hills south of Appleby. Among them I found one or two which were about twelve feet in diameter. On the south side of the calcareous zone, the granite blocks are incomparably more abundant; and on approaching Wastdale Head (a few miles south of Shap), where the granite is *in situ*, they literally cover the ground. Near Shap Wells there is a rolled mass of granite fifteen feet long, ten feet wide, and eight feet high.

Bowlders on Kendal Fells, &c.

5. Equally striking examples may be found on the south side of the mountainous region. On the flat tops of the calcareous hills on the west side of Kendal are many rounded blocks, apparently drifted from the green slate formation at the head of Kentmeer and Long Sleddale. These calcareous hills are now separated by deep valleys from every part of the slate formation. Similar phenomena appear on several parts of the mountains between Kendal and Sedbergh, and among the rolled masses are a few bowlders of shap granite. The instances now given are sufficient for my present purpose; for they completely bear out the observations by which they were preceded.

Proofs of Diluvian Action at the Tops of the Mountains.

VI. It is stated by Buckland (*Reliquiæ Diluvianæ*, p. 221), "that all mountain regions he has ever visited bear, in the form of their component hills, the same evidence of being modified by the force of water, as do the hills of the lower regions of the earth." My own observations, as far as they go, confirm the truth of this remark. Some of the highest mountains of Cumberland and Westmorland, which consist of a soft decomposing slate, are as plainly modified by the action of denuding currents as any of the secondary ridges of our island. We must, however, remember that the earth's surface has been ravaged by the action of water during several distinct catastrophes, and that the present modifications in the form of some of our mountain chains *may*, therefore, have been effected during some epoch long antecedent to that of the diluvial gravel. To prove that the floods which produced the superficial gravel have swept over the tops of the highest mountains, requires, therefore, more direct evidence than that which is afforded by the external forms of the mountains themselves.* I think it has already been proved that diluvian torrents have swept over every part of the Cumberland chain; because we find water-worn masses, derived from the highest elevations of the country, imbedded in the diluvial loam which covers almost all the neighbouring plains; and because we find large bowlders of the same rocks scattered over many parts of the mid region of the mountains, in situations to which they could never have been drifted by any less powerful agent than that to which they have been ascribed. I may also observe that the bowlders in question, at whatever elevation, are all in the same state of preservation, and all appear, as far as we can judge from their external characters, to have been produced at the same epoch.

Admitting the fact that the waters of a great inundation have

* For the direct evidence offered on this subject by Prof. Buckland, see the "*Reliquiæ Diluvianæ*," p. 221—223.

swept over some of the highest elevations of the earth, it is still obvious that true diluvial deposits must necessarily be of rare occurrence near the crests of mountain chains. On this account I thought myself fortunate in being able to discover two or three examples of such deposits among the mountains of Cumberland.

Sca-fell.

1. In the deep water-worn channels which descend from Scafell towards Burnmoor Tarn, are great accumulations of *detritus*, which, when I visited the spot in 1822, I considered to be undoubtedly diluvial. These accumulations are apparently connected with the transported blocks which are scattered over the ground between Barnmoor Tarn and Wastdale Head, and exactly resemble the *detritus* which still further down is accumulated in the valley of the Mite.

Ridge, near Red Pike.

2. On the very top of the lofty ridge which separates the valleys of Ennerdale and Buttermere, are most striking and unequivocal proofs of the action of diluvian torrents. Between Red Pike and Ennerdale Scaw, the top of the ridge is partly composed of syenite, and partly of a soft variety of clay slate. A smooth round-topped hill (called Starling Dod), composed of the soft slate, forms the highest part of the crest between the two summits before-mentioned. I was persuaded, before I ascended this hill, that its singular form must have been produced by the action of water; and on reaching its summit, which is about 2500 feet above the level of the sea, I found it covered with water-worn bowlders of red syenite and other rocks drifted from the more lofty eminences of the same ridge near Red Pike. The same kind of bowlders are found near the top of Mellbreak, a mountain which overhangs the west side of Crummock lake; and they may be traced on the sides of the water-worn hills, and down the valleys which communicate with Loweswater and Crummock foot; and from thence the descending currents have drifted them into the lower regions of the district where they are mixed with the diluvium of the plains.

Borrowdale Fells, &c.

3. Near the top of Glaramara, one of the mountain crests of Borrowdale, and at the back of the Hay Stacks, near the top of the ridge between Ennerdale Head and Buttermere, I saw several bowlders which had been caught among the serrated edges of those rugged elevations. The transported blocks were not of a kind to enable one to point out the spot from which they had been drifted; but their presence was enough to demonstrate the former action of violent disturbing forces which had affected the highest points of the mountain region.

To account for such phenomena as those above described, by the bursting of lakes, of the existence of which we have no proof; and which, had they ever existed, could only have existed at much lower levels, would be to adopt an hypothesis contradicted by the very facts which it is intended to explain. The condition of the transported blocks, their association with others which have descended into the mid region, and their identity with many other masses which are imbedded in the diluvium of the plains, forbid us to ascribe their appearance to any of the more ancient catastrophes in the physical history of the earth. The conclusion then to be drawn from them is obvious, and is in accordance with the other facts which have been stated in this paper.

Directions in which the Shap Granite has been drifted.

VII. The great uniformity in the mineralogical character of the rocks in many parts of Cumberland, often prevents us from ascertaining the direction in which the diluvial bowlders have been drifted from their native beds. This difficulty we do not meet with in following the blocks of Shap granite, as they cannot be confounded with any other rocks in the north of England. It has already been stated that they almost cover the ground in many places near Shap; and that they have been lifted over the escarpment of the carboniferous limestone, and drifted over the hills near Appleby. I may now add, that they have been scattered far and wide over the plain of the new red sandstone—that they have rolled over the great central chain of England into the plains of Yorkshire—that they are imbedded in the diluvium on both banks of the Tees—and that a few straggling blocks have, if I mistake not, found their way to the eastern coast.

The passage of the same kind of granitic blocks into the valley of the Kent is, if possible, still more difficult to explain by the operations of any known agent. For the granite only exists *in situ* on the very outskirts of the mountain group, and almost abuts against the calcareous zone near Shap wells. Yet a set of gorges have been opened out of the higher and more central parts of the group, through which the granite bowlders have been driven (in a direction exactly opposite to that in which they have been already traced), and from which they have not only descended in great abundance into the valley of the Kent, but have also been drifted into a part of the ridge between the Kent and the Lune. With these remarks on the extraordinary directions in which masses of Shap granite have been drifted from their native bed, I terminate my observations on the position and extent of the masses of incoherent *detritus* which lie scattered over many parts of our island.

Concluding Remarks.

As the general result of the facts detailed in this and the preceding paper, we may conclude—that the floods which produced the diluvial detritus swept over every part of England—that they were put in motion by no powers of nature with which we are acquainted—and that they took place during an epoch which was posterior to the deposition of all the regular strata of the earth, and prior to all known accumulations of alluvial matter.

We have evidence enough to justify us in extending the same conclusions to every part of the European basin, and there is some evidence which makes it probable that they may be extended to the remotest parts of the earth's surface. Indeed the mighty disturbing forces which produced the accumulations of diluvial *detritus* between the western extremities of Europe and the central plains of Asia, must probably have acted with sufficient energy to leave some traces of their power over every quarter of the globe. On the continent of America the succession of formations seems to be very nearly the same with that of our own country; and over all the regular strata, there occur in many places alluvial and diluvial formations in every respect like those of Europe. It is, therefore, to say the least of it, probable, that the diluvial phenomena of Europe and America belong to the same epoch.

The actual duration of the diluvian era, it is of course impossible to ascertain; for as the powers of the agent are unknown, it is obviously impossible for us to form an estimate of the time which was necessary to the production of such effects as are visible on the earth's surface. The facts which have been detailed seem, however, to make it probable that the floods which produced the diluvial gravel were sudden and transient.

In the present state of our information, we have certainly no evidence to prove that all the highest elevations of the globe were submerged by the diluvian waters; for the form of the great mountain chains may have been produced by some more ancient catastrophe, and we have no right to assume the existence of diluvial *detritus* in parts of the world which have not been examined, or which are inaccessible. We have, however, direct evidence to prove, that the diluvian floods acted on some of the highest points of Europe, and it is probable also that they have acted on some of the highest parts of Asia.

As we are unacquainted with the forces which put the diluvian waters in motion, we are also, with very limited exceptions, unable to determine the direction in which the currents have moved over the earth's surface. Many parts of the north of Europe seem to have been swept over by a great current which set in from the north. In some parts of Scotland there has been

a great rush of water from the north-west.* The details given above, show that the currents which have swept over different parts of England have not been confined to any given direction. It may, perhaps, be laid down as a general rule, that the diluvial gravel has been drifted down all the great inclined planes which the earth's surface presented to the retiring waters.

That the details given in the preceding papers tend, as far as they go, to confirm the general argument of Buckland's "*Reliquiæ Diluvianæ*" cannot admit of doubt. Indeed, the facts brought to light by the combined labours of the modern school of geologists, seem, as far as I comprehend them, completely to demonstrate the reality of a great diluvian catastrophe during a comparatively recent period in the natural history of the earth. In the preceding speculations, I have carefully abstained from any allusion to the sacred records of the history of mankind; and I deny that Professor Buckland, or any other practical geologist of our time has *rashly attempted* to unite the speculations of his favourite science with the truths of revelation.†

The authority of the sacred records has been established by a great mass of evidence at once conclusive and appropriate; but differing altogether in kind from the evidence of observation and experiment, by which alone physical truth can ever be established. It must, therefore, at once be rash and unphilosophical to look to the language of revelation for any direct proof of the truths of physical science. But truth must at all times be consistent with itself. The conclusions established on the authority of the sacred records may, therefore, consistently with the soundest philosophy, be compared with the conclusions established on the evidence of observation and experiment; and such conclusions, if fairly deduced, must necessarily be in accordance with each other. This principle has been acted on by Cuvier, and appears to be recognized in every part of the "*Reliquiæ Diluvianæ*." The application is obvious. The sacred records tell us—that a few thousand years ago "the fountains of the great deep were broken up"—and that the arth's surface was submerged by the waters of a general deluge; and the investigations of geology tend to prove that the accumulations of alluvial matter have not been going on many housand years; and that they were preceded by a great catastrophe which has left traces of its operation in the *diluvial detritus* which is spread out over all the strata of the earth.

* This is proved in an original and excellent paper, published by Sir James Hall, in the Transactions of the Royal Society of Edinburgh, vol. vii.
See also the "*Reliquiæ Diluvianæ*," p. 201—205.

† See the Edinburgh Philosophical Journal, No. 22, p. 304.

Between these conclusions, derived from sources entirely independent of each other, there is, therefore, a general coincidence which it is impossible to overlook, and the importance of which it would be most unreasonable to deny. The coincidence has not been assumed hypothetically, but has been proved legitimately, by an immense number of direct observations conducted with indefatigable labour, and all tending to the establishment of the same general truth.

APPENDIX.

[The following account of the drainage of a part of the fen lands bordering on the Wash of Lincolnshire, is principally abridged from Dugdale on "The History of Imbanking and Drayninge," chap. 54; and from "Badeslade on the Navigation of King's-Lynn, and of Cambridge." It was intended to appear in the form of a note to the fifth section of a paper in the *Annals of Philosophy* for April last; but it was not transmitted to the Editors in time for the press.]

A short account of the drainage of a part of the fens, bordering on the Wash, during a period within the reach of authentic records, will explain and confirm the assertion in the text.* In the early parts of that period, the drainage was effected in the following manner: 1. By the channel of the Witham, which had nearly the same course which it has at the present time. 2. By the Welland, which, after descending by Stamford, Crowland, and Spalding, united with the waters of the Glen in the estuary, north of Holland-fen. 3. By the Nene, which, after passing Wansford and Peterborough, descended by Whittlesea-meer, Ugg-meer, and Ramsey-meer to Benwick, where it was joined by the Old West-water, one of the branches of the Great Ouse; from Benwick it flowed on the north side of March and Doddington (which stand, if I mistake not, on low diluvial hills) to Upwell, where it was joined by the Welney river, then the principal branch of the Great Ouse; and from Upwell the united waters proceeded directly to Wisbeach, anciently called Ousebeach. 4. By the Great Ouse, which, after passing Huntingdon and St. Ives, descended to Erith (a small village at the SW. end of the old and new Bedford rivers) ~~when~~ where it divided into two branches. One called the Old West-water ran to Benwick, as before stated, and there united with the Nene. The other branch, now called the Old Ouse (sometimes erroneously marked as the Old West-water), descended by Cottenham fen, and was joined by the Cam a few miles above Ely. After passing Ely, it was joined by the Mildenhall river; and it then passed, by the way of Littleport and

* See *Annals* for April, Editor's note, sect. 5.

Welney, to Upwell; where (as above stated) it joined the waters of the Nene and descended to the sea at Wisbeach. 5. By the Little Ouse (then a very inconsiderable river), which (after passing Brandon, and being joined by some small tributary streams from the Norfolk side) fell into the sea at Lynn. In the preceding account, all the old artificial drains, and several minute bifurcations of the rivers, after they reached the alluvial delta, are intentionally omitted.

As early as the twelfth century, the accumulations of alluvial silt near the mouths of the Welland and the Nene, caused a great back-water; and in the early part of the thirteenth century (by the great rise of the fen lands near the coast) the out-fall of the waters by some of the old channels entirely failed. During this time, the bed of the Little Ouse, not having been silted up in the same manner, was much below the mean level of the alluvial delta, extending through the mouths of the other rivers above mentioned; and a great drain was consequently cut from Littleport Chair to Rebeck, making the first direct communication between the Great and Little Ouse. The effect was exactly what might have been anticipated. The waters which had been pent up at a higher level descended with irresistible force through this new drain into the channel of the Little Ouse, and so escaped into the sea at Lynn. About this time the out-fall at Spalding had so completely failed, that the waters of the Welland found their way through the Catswater into the Nene; and a new direction having been given to all the currents, in consequence of the channel which was now opened below the level of the ancient out-fall at Wisbeach, the united waters of the Nene flowed back into the Great Ouse through the Old West-water, through the Welney branch, and through all the other cross drains of the country; and were then conveyed by the new communication into the Lynn river. In this way, for many years, nearly all the waters of the alluvial delta, south of the Witham, found their way into the sea at Lynn: and the river, which had formerly run between banks which were not more than twelve perches asunder, was, after the changes above described, more than a mile wide.

Many attempts were made to prevent this great discharge of waters through the Ouse. In the year 1292, several dams were constructed near Upwell, to prevent the influx of the Nene. But they produced such ruinous effects on many parts of the marsh lands, and on the banks of the Ouse as far as St. Neots, that in 1332 they were ordered to be destroyed. For many years afterwards, the great drainage of the delta was effected nearly in the manner above described.

In the year 1490, the discharge by the Ouse was partially relieved by a great cut (called Morton's *Leam*) from Peterborough to Guyhirn near Wisbeach. This was intended to

convey the waters of the Nene direct to their old channel at Wisbeach, but was never entirely effective before the year 1638: when Vermuyden, under King Charles I. erected high banks on each side of the *Leam*, and opened out a channel to the sea. Since that time the Nene has continued to flow down to the sea by Wisbeach.

Notwithstanding the indirect nature of the new drainage which conveyed the waters of the Welland, the Nene, and the Ouse, into the sea by the Lynn channel, the fens appear for many years afterwards to have been in a good condition; a fact which can only be explained by the low level of the great outfall. In course of time, however, the new channels began to silt up, and new works became necessary. Of these works, the old and new Bedford rivers were the most important, extending from Erith to Salters Lode, a distance of about twenty miles. Soon after the year 1648, when the new Bedford river was completed, the waters of the Ouse were shut out by a sluice at Erith from their old channel, so that they did not mix with the waters of the Cam and its tributary branches, till they had been conducted by the new drainage to Salters Lode. These new works appear from the first to have been injurious to the natural drainage of the Cam; for the floods of the Ouse by the new passage reached Salters Lode much sooner than the floods of the Cam; moreover, the bottom of the new Bedford river was about eight feet above the bottom of the old Ouse. On both these accounts, the banks of the Cam were perpetually flooded by the back-waters of the Ouse. One great flood of the Ouse in 1720, is said to have backed up the Cam for twenty days, and to have silted up a part of the old channel below Ely, to the thickness of three or four feet. These ruinous effects have been partly counteracted by the erection of different sluices; which, although affording a cure for an immediate evil, have ultimately produced the very evil they were intended to remedy; for, partly by their agency, the whole bed of the Cam is now silted up to the level of the Bedford rivers.

If such extraordinary effects as those described in this note be produced by the accumulation of alluvial matter in course of a few hundred years, we may be well assured that the whole form of the neighbouring coast must have been greatly modified by the same causes acting without interruption, and without any modification from works of art, for 3000 or 4000 years.

Printed by C. Baldwin, New Bridge-street, London.